ART. VIII. — 1. *Vesuvius.* By JOHN PHILLIPS, M. A. Oxford. 1869. 12mo.

2. *Histoire Complète de la grande Éruption de Vésuve de* 1631. Par H. LE HON. Bruxelles. 1866. 8vo.

3. *Reise der Oesterreichischen Fregatte Novara um die Erde in den Jahren* 1857, 1858, 1859. Geologischer Theil, Erster Band, Erste Abtheilung, Geologie von Neu-Seeland. Von DR. FERDINAND VON HOCHSTETTER. Wien. 1864. 4to.

4. *Voyage Géologique dans les Républiques de Guatemala et San Salvador.* Par MM. A. DOLLFUS et E. DE MONT-SERRAT. Paris. 1868. 4to.

5. *The Natural System of the Volcanic Rocks.* By BARON F. RICHTHOFEN. Extracted from the Memoirs of the California Academy of Sciences. San Francisco. 1868. Pamphlet.

WE have placed at the head of this article the titles of a few of the many volumes devoted chiefly to the subject of volcanoes which have issued from the press during the past few years. To give a complete list of the volumes and papers in which the phenomena of volcanism have been described and discussed, even if only the productions of the last five years were to be included in it, would require many pages. On the subject of the volcanic island of Santorin alone, at least six different works were published during the year 1868. One author, Le Hon, gave, in 1866, a complete history of an eruption of Vesuvius which took place two hundred and thirty-eight years ago; while several other writers, some of them known as geological authors and others not, have taken advantage of the recent period of activity of that interesting volcano to serve up portions of the mass of the old material in a new form, adding in some cases new facts of value to the previously existing stock, but generally relying for their chances of success rather on elegance of typography, or other extrinsic circumstances, than on scientific accuracy or originality of ideas. The reason of the exceptional activity in this department of book-making is partly that the volcanoes themselves — at least several of those best known — have been unusually active, and partly because the fashion of illustrated and sen-

sational books on scientific subjects has been set, and of all the subjects which geology presents there is none which so excites the popular mind as the phenomena of volcanoes and earthquakes.

Earthquakes are events simply fearful; there is nothing about them which is not appalling in its nature. They come without warning, and leave nothing but dismay and ruin behind. Even the minor shocks are terrible, and more alarming in proportion to the number of times they have been experienced. It is only in California that an attempt has been made to pooh-pooh an earthquake; but even there the hollowness of the derision was but too evident. In an earthquake-shaken country the time that elapses between the instant when one perceives that an earthquake wave is approaching and that when its first effect is felt is one into which a thousand apprehensions can be crowded. Then, if ever, one feels the utter insignificance of man as an integral part of creation. The blow may fall lightly and leave no sensible trace behind; or, on the other hand, it may crush and overwhelm. The regulating screws of the horrid machinery are invisible. There is no reason why one should await with more calmness the approach of an earthquake shock than, with his head on the anvil, the falling of a steam-hammer, not knowing beforehand at what point the ponderous mass is to be arrested by the engineer in charge of the machine.

Volcanoes, on the other hand, give in almost all cases some previous warnings of their intention to change their usual quiescent state for one of destructive activity. Their disastrous effects can often be to a large extent avoided by flight. It is only very rarely that an eruption is so sudden and violent as to overwhelm and destroy without previous and oft-repeated warnings. Again, eruptive volcanic action is usually prolonged over many days or weeks, or even months, and the phenomena exhibited are usually — if the eruption is on a large scale — of surpassing grandeur, from a picturesque as well as from a scientific point of view. Perhaps there is no scene offered by any play of nature's forces so wonderfully attractive as that of a great volcanic eruption, especially when seen by night. The combination of every conceivable element of the picturesque

and the sublime afforded by the great outbreaks of Kilauea, as reported by the few who have had the good luck to witness some of them, may be mentioned as an instance in point.

No wonder, then, that the subject of volcanoes has always been an attractive one to the general, as well as to the scientific, traveller and writer, and that such a great number of volumes have been published, and are still publishing, treating either of volcanoes in general or of particular eruptions or periods of eruptive activity. The work of the veteran Oxford professor, John Phillips, the title of which is placed at the head of the list preceding this article, is one of the most noticeable of those possessing a somewhat popular character. Within the limits of three hundred and fifty pages it gives a succinct history of Vesuvius and of the adjacent volcanic region so much visited by travellers, and is on all points exact and clear. The illustrations of the volume are numerous and effective, although not elaborate, and very far from sensational. The book is exactly what was desirable as a guide to travellers of scientific tastes, and may be consulted with profit and pleasure by the professional geologist. It contains, besides, a catalogue of Vesuvian minerals. There is also a chapter devoted to the theory of "volcanic excitement," — a subject on which much has been written, especially of late, but in regard to which it must be admitted that we have still much to learn.

The work of M. Le Hon, placed second on our list, is especially valuable as containing a large map, which appears to have been carefully constructed, and which exhibits all the flows of lava from Vesuvius between the years 1631 and 1861. This is the only map which professes to give with any approach to exactness the position of these masses, and evidently it could not have been produced without considerable labor and without numerous excavations. The description of the eruption of 1631 is carefully compiled, and gives a good idea of this the most devastating of all the modern outbreaks of Vesuvius. By this eruption it is probable that at least four thousand persons lost their lives in various ways, while more than forty towns and villages were destroyed, the pecuniary

losses being estimated at twenty millions of ducats, — an enormous sum at that time.

The volcanic phenomena of a far distant but exceedingly interesting region — New Zealand — are brought to our notice for the first time in a comprehensive manner by Dr. Hochstetter, in two separate works, — one, in royal 8vo. form, of a popular character, entitled simply "Neu-Seeland"; the other, a volume of the series published by the Austrian government as the official account of the voyage of the frigate Novara, made in the years 1857–59. The first-mentioned work was published by Cotta, in 1863, with every luxury of adornment, and is one of the most attractive books — half scientific and half narrative — ever issued. The quarto official volume is also beautifully printed and illustrated, and is largely devoted to a description of the New Zealand volcanoes, as well as of the wonderful geysers, hot-springs, and solfataras which form so peculiar and attractive a feature of the island, and which are admirably represented in the chromo-steel plates of the popular volume and the chromo-lithographs of the other. These indicate a type of geological scenery resembling that of the geysers of Iceland, but on a grander scale, and with the peculiar added beauty of a wonderfully interesting and abundant vegetation. Dr. Hochstetter's books are rich in information about a new and remarkable region, but they are very little encumbered with generalities or theoretical views.

Almost equally magnificent in its typography and style of publication is the work placed fourth on our list, — an official publication of the French government, issued from the *Imprimerie Impériale*, as an instalment of the results of the scientific mission instituted by the Emperor for exploring Mexico at the time when his unfortunate military expedition to that country was planned. In carrying out this exploration, MM. Dollfus and Mont-Serrat — neither of them a geologist of reputation — spent a little over two years in that region, eight months of it in Central America. The results of their investigations have been laid before the public in the form of a ponderous quarto, in which, as in many other works of French savans which treat of the geology of parts of our continent, there is but little that is new, while, on the other hand, it con-

tains many blunders. The Emperor has been unfortunate in the representatives of geological science whom he has sent to the American continent. M. Laur, who visited California some ten years ago, and made a report on its mines, showed a remarkable tact for misapprehending the plainest and most important facts, and drawing erroneous conclusions; as, for instance, when he announced that the yield of the Comstock Lode would never exceed three millions of dollars a year, whereas, in reality, it soon after reached twelve millions. About half of the volume of MM. Dollfus and Mont-Serrat is taken up with remarks on the volcanoes of Central America, and it is astonishing how little there is of original and valuable matter to be found in it. One is more annoyed still, on examining the beautifully engraved illustrations, to find that they bear evident marks of the sensational style; the slopes of the cones are all enormously exaggerated, and no data are given by which these errors can be corrected. A few simple outlines plotted from actual measurements would have been worth more than the whole dozen and a half of costly steel plates which are given, the style of which takes us back to the dark ages of the illustrations to Humboldt's "New Spain." One should compare them with the drawings and sections illustrating M. Hartung's books on the Azores, Madeira, and Porto Santo, to see the difference between fancy and real work.

Baron Richthofen's quarto pamphlet of a little less than a hundred pages, with no illustrations, is entirely different from most of the works already cited, since it addresses itself exclusively to the professional geologist. It is the result of long observation and of much study bestowed on the volcanic rocks by an able and experienced observer in different parts of the world. In it many of the most difficult points in the theory of volcanoes are discussed in such a manner as to make its study imperative on all who desire to form an original opinion in regard to the subjects with which it deals. We shall refer to it further on, or at a future time, when the theory of volcanoes and earthquakes is under discussion.

In a previous article we endeavored to give a systematic view of the present condition of our knowledge of earthquake phenomena, so far as their external manifestations are con-

cerned. We discussed the data of the earthquake catalogues with reference to the geographical distribution of seismic areas, to the relations of time of earthquake shocks, and to their connection with movements and conditions of the atmosphere. We had occasion to refer more than once to the relations between volcanoes and earthquakes both in time and space, and thus prepared the way for a discussion of the causes of these truly wonderful and most closely connected phenomena.

Before entering on this discussion, however, we must become more fully acquainted with the facts concerning volcanoes, and it is with these that this article will be occupied, leaving for a third and final one of the series, an attempt to show how far science is able, at the present day, to throw light on those workings of unseen forces which are manifested in the earthquake shock, the volcanic eruption, the rising and falling of the land, and the formation of mountain chains, — for all these are effects of one and the same cause, or, at least, of one set of causes so intimately allied with each other that the discussion of any one of them must necessarily include that of all the others.

In pursuance of this plan, then, we purpose, in this article, to give an outline of what is known in regard to volcanoes, having reference chiefly to their external manifestations, such as form, geographical distribution, nd their different phases of repose and action. This will prepare the way for us to get some idea of the nature of the forces at work below; for a volcano is a sort of happy accident, which lets us into some of nature's secrets, — a peep-hole through which we may get a glimpse of the interior of the earth. It is evident that, if a great smelting establishment were buried so that no part of it should be visible except the top of the tall chimney, from which gases were issuing, and some piles of slags accumulated on the outside, and we had to report on the nature of the processes going on below from these imperfect data, the investigation would require no little scientific knowledge and ingenuity, and probably some time would elapse before a guess could be hazarded as to the character of the work of which these gaseous exhalations and slags were the only tangible result. So it is with volcanoes: we collect and analyze their products, whether solid, fluid, or

gaseous; we note the times and places of these manifestations of the internal forces and their correlations with other natural phenomena; we avail ourselves of every conceivable source of information touching the subject, and reason to the best of our ability on the whole mass of evidence thus obtained. And yet the result, it must be confessed, is far from satisfactory. There are many obscure points in the theory of volcanoes and earthquakes; and if the general cause of the phenomena of volcanism is in the opinion of most geologists correctly determined, yet in regard to the precise mode of operation of the internal forces there is great discrepancy of opinion, even among those who have devoted most time to this branch of inquiry.

A volcano is a mountain, hill, or area of the earth's surface, connected with some more or less deeply seated portion of the interior by a canal or passage, through which solid or gaseous materials are brought to the surface. It is almost invariably the case that the substances thus ejected are intensely hot, the rocky material often pouring forth in a condition of igneous fluidity, and the term "lava" is applied to anything which has flowed in this way and which in cooling consolidates into rock. Elevations which would, according to the definition just given, be included under the head of volcanoes, but which emit only water with paroxysmal violence, are usually called "geysers." These are rare and on a small scale as compared with proper volcanoes. Orifices from which mud is thrown out, called "mud-volcanoes," are not uncommon, but are usually of small dimensions, and the temperature of the substances they eject is in many instances raised but little above their ordinary temperature.

Volcanoes are called "active" if they have within a comparatively recent period given indications of eruptive action. The term "dormant" may be used to designate that peculiar condition when the internal forces have remained quiet for a great length of time, so that only faint traces of activity are still visible; and if all chemical action has ceased, and there is no record in history of any outbreak, the volcano or volcanic region is considered and called "extinct." Yet it is not an easy thing to draw the line between dormant and extinct volcanoes.

Thus Epomeo, on the island of Ischia, remained entirely inactive for seventeen hundred years. So Vesuvius was never known in history as an active volcano until A. D. 79. A great saucer-like depression, overgrown with wild grapes, in which Spartacus once camped with ten thousand men, marked the position of its crater, and Herculaneum and Pompeii were two populous towns at its base. By the well-known eruption of that year, these two towns were overwhelmed, — greatly to the inconvenience of their inhabitants, no doubt, but immensely to our advantage, — the whole adjacent region devastated, and the mountain built up into an entirely different shape from that which it had had before. From this time on, the eruptions continued, without any long periods of repose between them, until the fourteenth century, after which there was quiet for nearly three hundred years. During this period of repose the crater became filled anew with a forest vegetation, and only a couple of hot-springs gave evidence of the forces slumbering beneath. All of a sudden, again, in 1631, a furious eruption took place, and seven streams of lava flowed down the slopes of the mountain at one time. Since that, Vesuvius has almost always been uneasy, there being rarely an interval of rest of more than ten years, and, of late, the eruptions have been very violent and frequent. The Gunung Gelungung, one of the great volcanoes of Java, was, and had been from time immemorial, perfectly quiescent, and the site of the present crater was a broad valley, the inhabitants of which had never dreamed of anything but the most peaceful security. But suddenly, in the middle of a fine day in October, 1822, they received notice to quit, in the form of a violent explosion beneath their feet, which proved to be the commencement of one of the most fearfully destructive volcanic eruptions on record.

There are but few volcanoes which are permanently active, and those which are thus in constant eruption are usually far from violent. Paroxysmal, powerful action occurs only occasionally, sometimes recurring, after short intervals, then slackening and perhaps ceasing altogether, or, after a long period of repose, say hundreds or perhaps thousands of years, beginning again.

We have in the moon the best possible specimen of thor-

oughly played out volcanism. The most careful watching of the surface with powerful telescopes seems, thus far, to have failed to reveal any evidence of changes taking place there. And since there is neither water nor air to produce erosion or disintegration of the volcanic surface, it seems pretty clear that it will remain as it now is for an indefinite length of time.

In dividing terrestrial volcanoes into extinct, dormant, and active, it must be understood, then, that these terms are used to express our general opinion with regard to their condition, based on a variety of circumstances, and not as indicating any positively established criterion by which the different classes can be distinguished from each other. We speak of the volcanic region of Central France, as "extinct," because we know that a long time has elapsed since any indications of activity have occurred there; this has been ascertained by studying the amount of erosion which has taken place in the lava currents and in other ways. Yet the pouring out of a portion, at least, of the vast mass of volcanic material there visible took place, in all probability, after the appearance of man on the earth, although at an epoch immensely remote as compared with historical time. Neither can any conclusive reason be given why volcanic activity should not again manifest itself in this region.

A volcano may be considered as only dormant, and not extinct, when in the so-called "solfataric condition." This name is derived from the Solfatara, near Naples, where there has been no eruption since 1198, but where vapors and gases are constantly issuing from the region of the old crater. These vapors consist mainly of steam, mixed to some extent with sulphuretted hydrogen, and also with sulphurous acid, chlorohydric acid, carbonic acid, and nitrogen gases. The abundance of the sulphuretted hydrogen is usually testified to by the deposits of sulphur, so often met with in the craters of old volcanoes, and undoubtedly formed by the decomposition of this gas; besides, the nose has no difficulty, if no satisfaction, in detecting its presence. Steam and sulphuretted hydrogen usually predominate largely among the products of solfataric action. The other gases mentioned generally, but not always, occur in smaller quantity. Boracic acid, petroleum,

specular iron, chlorides of the alkalies, realgar, and orpiment are also occasionally observed among the gaseous emanations in old volcanic regions. Some observers testify to the existence of inflammable gases in sufficient quantities to produce flames, these gases being hydrogen and sulphuretted hydrogen; but there are other observers, equally distinguished, who have had frequent opportunities to examine volcanoes, both in action and at rest, and who have never seen any indication of flame. What is generally called fire, in eruptions, is, of course, simply the light or the reflection of the lava, which is intensely heated but not actually undergoing combustion.

During the solfataric condition of a volcano, its crater becomes blocked up with congealed lava, perhaps overgrown with forests and dense vegetation, and the signs of activity die out, until, as the last relic of former life, only a thermal spring may be found here and there, — an indication of the mighty forces slumbering beneath. Such is the present condition of nearly all the great volcanic cones on our own coast, from Arizona to Oregon.

Midway between the conditions of solfataric repose and of paroxysmal violence is another stage of activity, in which some volcanoes remain during long periods, while a few appear never to pass out of it into more violent action; others, however, remain in this condition of partial repose during the intervals between violent outbursts. At such times the crater and the channel connecting it with the interior remain open, and the lava can be seen in them maintaining a mobile condition, while occasional explosions of the surface of the melted mass take place, fragments of slag and cinders being thrown up and mostly falling back into the abyss from which they were hurled. This was the condition of Vesuvius when visited by the writer in November, 1843. At that time there had been no eruption of lava overflowing the lip of the crater since 1839, when the cavity was cleaned out, and left as a funnel three hundred feet deep, accessible to the bottom. From this time a smaller cone began to grow inside the large one, and in 1843 it was about fifty feet high, and could be reached by clambering down the walls of the old crater, the whole bottom

of which, around the foot of the new cone, was covered with lava, which was red-hot a few inches beneath the surface, but could in most places be safely walked on. From the vent a shower of cinders was thrown up every fifteen or twenty minutes; and although it was possible to climb to the summit of the cone on the windward side, with occasional calls for skill in dodging the projectiles, the orifice was too much occupied with ascending vapors to permit of anything below being clearly seen. This interior cone kept on growing by additions made to it from the falling materials, and finally, in 1847, the crater became filled, and the lava overflowed, running down on three sides at once. From that time forward Vesuvius became very uneasy, and finally a great eruption took place in 1850. This lasted about twenty days, and when it was over the summit of the mountain was left much changed in form, the old walls having been broken down, the central cone reduced in size, and a new crater formed, about two miles in circumference, and a hundred and fifty feet deep. The volcano then remained quiet from 1850 to 1855, when it became very active; again a grand eruption occurred in 1858, and slight ones in 1860 and 1861. Since the last-named year Vesuvius has rarely been at rest. During the winter of 1867 – 68 there was a great outburst of volcanic force, which lasted several months.

In the condition of half-repose just noticed as not uncommon between intervals of paroxysmal activity, observers are able to look down into the throat or channel of Etna, as well as of Stromboli, during the periods of repose between the eruptions, which take place with great regularity every ten or fifteen minutes. At such times the lava is seen to move up and down in the chimney; as it rises, its surface swells up into a great blister, which finally gives way to the tension exerted and explodes with a loud noise, the fragments being scattered and thrown up with great force; the column of melted matter then sinks back into temporary repose, and rises again after an interval of a few minutes. The same phenomena were observed on Sangay, one of the Quito group, a permanently half-active volcano, like Stromboli.

The most gigantic exhibition of this condition of the volcanic forces is to be seen in Kilauea during its quiet periods, when

the crater, which is three miles in its greatest diameter, has in it large pools of boiling and extremely fluid lava, which is continually thrown up in jets of from thirty to forty feet in height, that fall back into the pool before they have time to cool. These lakes of liquid fire vary in size according as the volcano is more or less active, and sometimes cover the whole area of the crater, the wind raising the surface in waves of molten rock, which dash against the encircling walls with an indescribably grand effect. The greater the liquidity of the lava, the less the force with which it is thrown up, for the jets of imprisoned vapors do not have time, in a very fluid material, to accumulate sufficient pressure to act with extreme explosive violence.

The phenomena which, we have seen, thus characterize the semi-active condition of volcanic activity are, in most respects, similar to those of the fully active state, differing rather in the degree of violence with which they are manifested than in kind. It seems, indeed, that the longer and more complete the repose of the volcano has been, the more violent its action when it once breaks out again. This is natural, for the resistance to an outburst must, as an ordinary thing, go on increasing the longer the vent remains stopped, and when this resistance is finally overcome the magnitude of the eruption will be proportionate to the force required to clear the way. The first recorded eruption of Vesuvius was the most violent of any which are known to have taken place; next to this in its destructive effects was that of 1631, occurring, as it did, after several hundred years of entire repose.

In regard to the precursors of a violent eruption, or the symptoms by which the approach of one may be detected, there is much uncertainty. It may be said, however, that a great outbreak is to be expected when the internal forces begin to show signs of uneasiness and the usual phenomena of half-repose to be intensified in their action. It seems a well-authenticated fact, that previous to an eruption of Vesuvius the wells and springs adjacent to the mountain begin to dry up. When volcanic cones are covered with snow it is not uncommon for the eruptions to be preceded by devastating floods, caused by its melting, the natural result of the gradual warming up of the mountain mass.

The following are the ordinary phenomena of violent eruptions: an appearance of fire; lightning; subterraneous noises, or thunder; ejection of ashes, cinders, or blocks of lava; the pouring out of melted lava; and, in connection with earthquake shocks, fissures in the earth and permanent changes in the level of the adjacent country.

Great volcanic paroxysms are often preceded by more or less violent earthquake shocks, which are both frequent and prolonged, but usually limited to the mass of the volcano itself or its immediate vicinity. Tremendous underground detonations are heard, sounding like the firing of heavy cannon or repeated volleys of musketry. These sounds are heard at all points at the same instant of time, showing that they are propagated through the crust of the earth and also that they come from a great distance beneath the surface. These explosive sounds have been heard simultaneously over areas of many thousand square miles. Thus the noise of the outbreak of the eruption of Temboro, on the island of Sumbawa, was heard all over Java, and everywhere supposed to come from some point in the immediate vicinity. It was distinctly audible at points two thousand miles apart. As the shocks and sounds continue, people become more and more alarmed and excited, and imagine that they see every kind of portent in the sky or in the conduct of animals. It is generally thought that an oppressive stillness pervades the atmosphere just before the moment of the great outbreak, and that dogs, swine, and geese exhibit peculiar indications of fear. How much reliance can be placed on the statements of the sensitiveness of animals to impending catastrophes, it is not easy to say; but it is evident that the circumstances of a great eruption are eminently favorable to a highly imaginative condition of the mental faculties.

The earthquake shocks preceding volcanic outbreaks take place while the internal conflict is going on between the imprisoned lava, seeking to find a vent, and the resistance offered by the weight and tenacity of the superincumbent crust. When the internal pressure which seeks relief in bringing up to the surface the material on which it is acting at last has its own way, the explosion is tremendous, the mass of the volcano

being shaken to its very foundations. As soon as the channel of communication with the interior is opened, which channel usually communicates with the bottom of the old crater, although not unfrequently opened through some new side fissure, the pent-up vapors and gases begin to escape with tremendous force, carrying up in the air, torn into fragments, rocky masses, which then fall and are thrown out again repeatedly, and thus, by friction against each other or by actual explosion, through sudden changes of temperature, are rapidly reduced to powder and carried off with the gases or vapors which rise from the chimney of the crater.

The ejection of vapor and ashes, as the comminuted fragments of lava are called, is thus described by Scrope, who was an eye-witness of one of the grandest eruptions of Vesuvius,—that of 1822. He says: "The rise of the vapor produces the appearance of a column several thousand feet high, based on the edges of the crater, and appearing from a distance to consist of a mass of innumerable globular clouds of extreme whiteness, resembling vast balls of cotton rolling one over the other as they ascend, impelled by the pressure of fresh supplies incessantly urged upwards by the continued explosions. At a certain height this column dilates horizontally, and — unless driven in any particular direction by aerial currents — spreads on all sides into a dark and turbid circular cloud. In very favorable atmospheric circumstances, the cloud with the supporting column has the figure of an immense umbrella, or of the Italian pine, to which Pliny the younger compared that of the eruption of Vesuvius in A. D. 79, and which was accurately reproduced in October, 1822. Strongly contrasting with this pillar of white vapor-puffs is seen a continued jet of black cinders, stones, and ashes, the larger and heavier fragments falling back visibly after describing a parabolic curve. This jet of solid fragmentary matter often reaches a height of several thousand feet, while the vapor pillar rises still higher. Forked lightnings of great vividness and beauty are continually darted from different parts of the cloud, but principally its borders. The continual increase of the overhanging cloud soon hides the light of day from the districts situated below it, and the gradual precipitation of the sand and ashes it contains contributes

to envelope the atmosphere in gloom, and adds to the consternation of the inhabitants of the vicinity."

If the volcano is one which emits lava, this rises gradually in the crater and finally overflows it at the lowest point, unless it succeeds in forcing its way through some side fissure. The molten mass finds its way down the declivity with a rapidity proportioned to its fluidity, overwhelming and destroying everything which it encounters. Clouds of vapor rise from the flowing mass, visible during the day, the exterior soon becoming covered with a dark crust of scoriæ, occasional fissures in which reveal, especially at night, the presence of the intensely ignited material beneath. The flow of lava from the volcanic vent indicates that the crisis of the disturbance is passed, and that there will thenceforth be a gradual slackening in the violence of the eruptive action.

Not a few volcanoes, however, never send out lava, but only ashes and cinders; these are usually the very large ones, as, for instance, the great cones of South America. It is also true that large volcanoes are less frequently than smaller ones the seat of great disturbances. The frequency of the eruption seems to be, in a measure, in inverse proportion to the height of the volcanic cones from which they proceed. Thus the lofty volcanoes of South America have rarely had more than one eruption each in a century; the Peak of Teneriffe had only three between 1430 and 1798. This is very natural, since the higher the cone the greater the resistance offered to an outbreak by the weight of the column. But the rule is not of universal application. Closely connected with the last-mentioned fact is another, previously suggested, namely, that the most fearful eruptions may be expected to occur after long intervals of repose. Both circumstances indicate very clearly the accumulation of force necessary to overcome increased resistance.

At night the column of vapor and ejected solid material appears red, not because it is actually a column of flame, but partly because it is illuminated by the reflection from the red-hot lava below, and also because the fragments carried up in it are themselves intensely heated. The fact that the column remains perpendicular all the time is a proof that it is not a

flame, for, if that were the case, it would be swayed by the wind; but one of the most characteristic features of an eruption is, that the pillar of fire seems to stand immovable amid the "wreck of matter" around it.

The electrical phenomena of a great eruption are extremely interesting. The upward rush of heated vapor gives rise to furious disturbances in the condition of the atmosphere, as is also the case, on a small scale, when steam escapes from an ordinary boiler through the safety-valve. A constant play of lightning goes on around the ascending column, and the noise of the thunder is mingled with the crash of the projected fragments of rock. Tremendous bursts of rain, or even hail, often occur at the same time, and from the same cause, — namely, the electrical disturbance of the atmosphere, — and the effect of the torrents of water rushing down the sides of the volcano is often more devastating than that of the lava itself.

The mass of ashes, scoriæ, or cinders thrown out in some volcanic eruptions is prodigious. In that of Vesuvius, in 1794, four cones were formed on a fissure nearly half a mile long, each with its separate crater, throwing up showers of red-hot cinders in such rapid succession as to appear like one continuous sheet of fire in the air. These showers really consisted of semi-fluid lava, which expanded in the air like soft paste. This continued for several days, so that the whole space above the crater seemed to be filled with the fragments, which formed a column a mile in circumference and rose to an immense height, then spread out, and seemed to cover a much greater area than the base of the mountain itself. Generally, however, these ejections of cinders are intermittent in character, sometimes following each other in rapid puffs, at others occurring as a succession of explosions at longer intervals.

The size of the fragments thus ejected is variable; often they are as fine as the finest dust, but sometimes the lava is thrown out in great masses. Thus Cotopaxi vomited forth, in 1533, blocks of rock ten feet or more in diameter. The so-called volcanic bombs shelled out by Vesuvius are usually from the size of the fist to that of the head. Generally they are irregularly rounded or pear-shaped; but in volcanoes in which the

lava is very liquid it comes down in masses which flatten out into cakes when they strike the ground. The finer fragments which in prodigious quantity accompany the larger, and usually vary from the size of a pea to that of a walnut, are now almost everywhere known by the Italian name of *lapilli*, or *rapilli*. The finer, sand-like material is called *puzzolana*, and the finest of all *ceneri*, or ashes.

One of the most curious features of the eruptions of some volcanoes is the prodigious number of small but perfectly formed crystals which are thrown out among the materials shot up from below. Vesuvius, which is a perfect treasure-chamber of interesting minerals, — while most of the American volcanoes are miserably provided in this way, — has furnished at times showers of beautiful crystals of augite, leucite, mica, and black garnet, the first-named being the most abundant. They seem to have existed ready formed in the semi-fluid lava, or else to have crystallized out suddenly at the moment of its solidification; which of these suppositions is the correct one is not thoroughly settled, although the first seems by far the most probable.

Vast masses of volcanic breccia occur in regions of eruptive rock, as for instance in California, where beds hundreds of feet in thickness are found covering many square miles of area, entirely made up of angular fragments of lava, of all sizes, which have evidently been ejected in the form in which we now see them. The explosions with which volcanic eruptions begin after long periods of tranquillity, and which sometimes pulverize the whole summit of the mountain mass in which they occur, give rise to prodigious accumulations of these broken masses of rock. The great eruption of Ararat, in 1840, was of this kind, a terrific explosion having torn open the side of the mountain and thrown off an immense mass of fragments, which were projected for miles in every direction, completely burying the town of Arguré. There was no eruption of lava; but frightful earthquakes and torrents of rain followed, washing down the detritus of the explosion in immense floods of mud, which were quite as destructive as lava would have been.

According to Junghuhn, the Javanese volcanoes now emit no lava, but only give rise to streams of brecciated material, which

have issued from the craters in that condition. The same author also gives a most interesting account of the great eruption of Pepandayan, which took place in 1772. At that time such a mass of fragments and blocks of lava was ejected that the upper part of the Garut valley, for ten miles in length, was filled with ashes and angular materials to the average depth of fifty feet, while in places the great blocks were heaped up in conical hills as much as a hundred feet in height. The distances to which such masses are thrown indicate the immensity of the force by which they are hurled into the air. Cotopaxi, for instance, in 1533, threw rocks from eight to ten feet in diameter to a distance of seven miles. The maximum height to which masses of lava have been thrown by Etna and Vesuvius, in different eruptions, is given by various scientific observers as from seven to ten thousand feet.

Towards the end of an eruption the ashes ejected grow finer and whiter, bearing all the marks of having been longer subjected to the triturating process by which the lava is reduced to powder. This is the natural result of the slacking off of the ejecting forces, the sinking down of the column in the chimney, and the consequent longer time that the materials are exposed to friction against each other. Some observers have thought, however, that the lava might in many cases be blown into fine powder by the sudden expansion into steam of the water it contained, at the moment the pressure was removed by its issuing from the crater, and there are some appearances which seem to render this view a probable one.

The finer the ashes thus ejected, the farther away from the volcano they fall. Carried by the wind, they are sometimes spread over vast areas of country, and the exceeding fineness of the material is testified to by the slowness with which it descends, sometimes filling the air so completely that the darkness of night reigns for days in succession. It is stated that, in the great eruption which devastated the island of St. Vincent in 1812, the fall of ashes on the island of Barbadoes, nearly a hundred miles distant, caused so profound an obscurity that a white handkerchief was invisible at five inches from the eye. The fall of ashes in the great eruption of Temboro, in Sumbawa, in 1815, produced so dense a cloud that it

was dark as night over the islands of Java and Celebes. Ashes fell on the islands of Sumatra, Banda, and Amboyna. West of Sumatra a layer of lapilli, two feet in thickness, floated on the sea, so that ships had difficulty in forcing their way through. A careful comparison of all the data, by Zollinger, led him to the conclusion that the ashes fell over an area of nearly one million of square miles, and that fully fifty cubic miles of material was ejected in this one eruption. Junghuhn, also, calculated the volume of the ejected materials of the same eruption to be one hundred and eighty-five times the dimensions of Vesuvius. The area over which daylight was shut off by this fall of ashes was nine hundred by seven hundred miles in extent, — that is, equal to the whole space in our own territory between the Mississippi River and the Atlantic Ocean. Coseguina, in 1835, covered with its falling ashes an area of nearly one thousand two hundred miles in diameter.

The destructive effects of these showers of ashes are fearfully increased by the torrents of rain which frequently fall in connection with great eruptions; these carry down the ejected materials in the form of great flows of mud, which descend the steep slopes with such velocity that they cannot be avoided, and of course completely overwhelm everything they reach. It was by such a *lava d'acqua*, or water-lava, as the Neapolitans call it, that Herculaneum and Pompeii were submerged and destroyed. For eight days and nights the torrents of mud poured down over those ill-fated towns, accumulating in places to the depth of over a hundred feet. It was the remarkable way in which these cities were overwhelmed that has preserved them so wonderfully for the inspection of people for almost two thousand years. There is no other possible manner in which they could have been thus hermetically sealed up, as it were, all the walls remaining standing, and everything in its place. Had a shower of ashes, for instance, fallen from above, all the buildings would have been crushed in; but the insidious mud-flow crept into everything, filling rooms, and even cellars, so gradually that nothing was disturbed or displaced. Herculaneum was afterwards covered with a layer of solid lava, and then built upon, so that the opening of that town has been much slower and more expensive; although, in proportion to

the amount of space uncovered, more interesting and valuable works of art have been disinterred than in Pompeii.

When these showers of ashes fall into the ocean, they gradually sink to the bottom, where they must eventually become consolidated into rock, which may be raised again to the surface in the course of the changes which are continually going on in the relative positions of sea and land. Thus are formed very extensive masses of stratified rock, which are at the same time both eruptive and sedimentary, or Pluto-Neptunean, as they have sometimes been called, as belonging to the two domains of the mythological rulers of the realms of fire and water.

It is by the constant addition made to their exterior by the falling masses of lava, ashes, and lapilli, that the cones of volcanoes are built up, — not only the dominating one of each volcano, but the secondary or minor ones, which are sometimes very numerous. These smaller cones form on the fissures which open frequently in the main cone, and which connect with the seat of action in the chimney of the volcano, just as that is connected with a still larger eruptive mass deep in the interior of the earth. Etna has more than seven hundred of these smaller cones around its base, some of which attain respectable dimensions, one reaching seven hundred feet in height, and another four hundred or more. On Vesuvius a fissure opened, in 1794, about nine hundred feet below the summit; this was two thirds of a mile in length, and eight new craters, with cones of scoriæ, were formed upon it.

Besides ashes and scoriæ, we expect, in most volcanic eruptions, to see rock rendered fluid by heat issuing from the crater, and it is to this molten rock that the name of lava is properly applied. The volcanic bombs, lapilli, and ashes are of course not fluid when ejected, although some of the larger masses sometimes reach the ground in a semi-plastic condition, so as to flatten themselves out into a sort of cake, as before mentioned. Different volcanoes and volcanic regions differ greatly in respect to the fluidity of their ejections. Those of Java, for instance, do not now throw out any molten lava, but only breccia, cinders, and ashes. The Hawaiian volcanoes, on the other hand, seem never to have ejected anything but lava of a high degree of fluidity. Vesuvius and Etna furnish both fluid and solid materials in abundance.

As a general rule, the very lofty cones do not emit currents of molten lava. Thus the great South American volcanoes throw out, almost exclusively, cinders and ashes. It may be stated that, in by far the larger number of instances, the great masses of lava which exist have come from low volcanoes, or still oftener from great fissures without any cones at all, in the form of "massive eruptions," as they are called, in which form, probably, by far the larger portions of the older volcanic rocks have come to the surface.

It is easy to see why, in lofty volcanoes, the lava should seek and find in many cases an issue at some point far below the summit. The higher the column, the greater the hydrostatic pressure, and when the resistance offered by this exceeds that which the sides of the mountain can oppose to it, the latter must give way, and the lava find a vent at the lowest available point. The constant battering of the internal walls of the chimney, kept up by the explosive forces within, gradually destroys the cohesive power of the material, breaks it up into fragments, or threads it in every direction with cracks, so that it finally yields to the repeated shocks, just as a piece of artillery fired with very heavy charges becomes at last too weak to resist any longer, and bursts into pieces. It is in this way that the fissures originate and become filled with molten lava, which solidifies in them, forming the dikes which are so common in volcanic masses, and which are so beautifully displayed in Etna, where its internal structure is revealed by the great cut into its heart called the Val del Bove.

The flow of lava, in volcanic eruptions, take place in very different ways, according to its consistency and the position of the point from which it issues. In general the crater fills up gradually, until the fiery liquid rises high enough to pour over the edge at the lowest point, when it runs down the slope with a degree of rapidity proportioned to its fluidity. The Vesuvian lava is usually very thick and ropy. One of the greatest currents of that volcano, — that of 1794, — which was over a thousand feet broad and from twenty to thirty deep, ran two and a half miles in six hours, or at the rate of 2,160 feet in an hour. The lava of Mauna Loa, on the other hand, is so liquid, that when it issues from the crater it pours down the steep

slope of the mountain, sometimes with amazing velocity. Thus Mr. Coan says of the eruption of 1855: "In one place only we saw the river [of lava] uncovered for thirty rods, and rushing down a declivity of from ten to twenty-five degrees. The scene was awful, and the momentum incredible. The fusion was perfect, and the velocity forty miles an hour." This lava, in making its way down the mountain-side, leaps over precipices in literal cascades of fire, presenting a most sublime spectacle. It occasionally forces its way out from a side fissure, — under immense pressure of course, — when it plays as a fountain, and the jets of liquid fire are reported by trustworthy authorities as rising sometimes to the height of six hundred or eight hundred feet.

Lava streams, however fluid the material may be, soon become covered, as they run down the sides of the volcano, with a consolidated crust. This hardened surface gradually thickens, and the bottom and sides also become more or less congealed, so that the flow continues through a sort of tunnel, as if it were being poured out of a sack made of its own substance. The surface gets broken up into great angular masses, which, by the motion beneath, are thrown into disorder and piled up on each other, as cakes of ice are on the sudden breaking up of one of our great rivers, — the St. Lawrence for instance. In the great eruption of Mauna Loa, already mentioned, the lava made its way seventy miles reckoned by the course of its flow, and forty in a direct line, to Hilo; and after its surface had become quite hard all the way, and there was no evidence of activity visible except the columns of vapor ascending from its head and foot, Mr. Coan believed that the interior was still moving downwards. This stream of lava was three miles wide on an average, and in some places three hundred feet deep. The masses of broken crust were piled up on it to the height of a hundred feet at various points.

The lava of Vesuvius seems more variable in its consistency than that of almost any other volcano. In the eruption of 1805, the velocity with which it issued from the crater was almost equal to that of the Mauna Loa current; on the other hand, the stream of 1822, when it reached Resina, moved at the rate of only five or six feet an hour. That of 1819 was in

motion, at the rate of three feet an hour, nine months after its issue. The rate of motion, measured by Dolomien, of one stream was a mile a year.

The low conducting power of lava is the reason why the interior of the mass can remain fluid so long and run beneath a crust of its own substance. The exterior hardens, can be walked over, or perhaps even cultivated, while the interior is still red-hot. This internal heat lasts for a long time. The lava of Jorullo was hot enough to light a cigar twenty-one years after its issue; and sixty-six years later it was still perceptibly heated, sufficiently so to give rise to *fumaroles*. One of the lava flows of Etna — that of 1787 — spread over a mass of snow, which, in 1830, still remained under it unmelted, while the overlying mass of rock was quite hot. The snow was preserved from melting by a cover of ashes, through which the heat was conducted with extreme slowness.

The manner in which volcanoes are built up by successive ejections of ashes, scoriæ, and lava, and the question whether the vast size of some cones is due in part to any other cause than this simple one of the piling up of erupted materials around a central orifice, now remain to be discussed.

The simplest possible form of a volcanic accumulation is that of the ordinary cinder cone, built up by a single eruption. Such cones are among the most common, as well as the most characteristic, features of almost every volcanic district. The coarse fragments thrown out heap themselves around the orifice as they fall, in the form of a circular bank, which, as the eruptive action continues, increases in size until it becomes a hill, having the form of a truncated cone, with a funnel-shaped hollow at the summit. A section of one will show that they are rudely stratified, and that the inclination of the strata decreases with the distance from the centre. These cones are of all sizes, from that of a hay-cock to that of a mountain. The "Puys," as they are called, of Central France, — Auvergne, Velay, and the Vivarais, — are hills of scoriæ thrown up in this way. Near Clermont-Ferrand there are above sixty cones strung together on a line more than sixty miles in length, and the fissure on which these were built up is continued in Velay and the Vivarais, with two hundred or more such cones arranged

in a belt twenty miles long. The shape of these accumulations of ejected materials varies with the conditions under which they are formed. When the wind blows steadily from one quarter, the materials will be more heaped up on one side, and this effect is very marked in the region of the trade-winds. A great many causes may be effective in modifying the cones thus formed. One is the issuing from them of a current of lava, by which the mass is broken down on one side; such breached cones are among the most common features of many volcanic regions.

An ordinary cone resulting from a single eruption consists, then, of a pile of scoriæ, lapilli, and other loose materials, with a single current of lava, which may have flowed from the summit, the side, or the base of the elevation, and which will be found spreading itself out over the adjacent region in a sheet or stream, proportioned in size to the extent of the eruption and the nature of the surface over which it has found room to extend itself. The result of repeated eruptions occurring from the same vent will be the gradual building up of a mass, which grows in size constantly but has the same kind of structure from top to bottom. Beds of solid lava alternate in it with others of fragmentary materials, and the whole system dips in all directions from the centre. It is not to be supposed, however, that any one of the beds of lava entirely surrounds the cone; on the contrary, if a horizontal section were made through such an accumulation, it would be seen that each outflow of molten rock has only added to the mass a portion of a concentric belt, so that the cone is built up by gradual additions of ejected materials, first on one side and then on another. Besides, there would be found, in many cases, a net-work of dikes of lava ramifying through the lower interior portion of the cone, and produced in a way which has already been indicated.

Almost all the older authors and many modern ones suppose that all volcanic cones have been built up in this simple manner. The theory originated by Humboldt and elaborated by Buch, and called the "crater-of-elevation theory," has found many warm supporters even among those who have worked long in volcanic regions, while it has been persistently opposed by most of the English geologists, especially by Lyell

and Scrope, as well as by Dana in this country. According to this theory, most great volcanoes consist of two portions, very distinct from each other in their mode of formation. The lower part, or base of the mountain as it might be called, consists of strata inclined at a less angle than the upper, and has not been formed by the accumulation of ejected materials, but consists, rather, of stratified masses, which may have been sedimentary beds deposited horizontally, or volcanic materials erupted from fissures under the ocean. In either case these beds are supposed, by the upholders of Buch's theory, to have been brought into their present inclined position by a "bubble-shaped elevation of the ground," caused by pressure of the volcanic forces confined beneath. On this inflated mass, through the centre of which the lava afterwards found its way, the cone of eruption is supposed to have been formed in the ordinary manner. In many cases, however, the process was a more complicated one. After the formation of the flattened dome-shaped mass, the volcanic energy, exerting itself at the base of the chimney by which the dome was penetrated, would fracture it in all directions, force lava into these fissures, swell out the mass, and gradually open a great crater at the summit, around the edge of which the strata would stand at a much greater angle than they originally had, it being maintained by Buch and the upholders of the elevation theory that lava could not consolidate in thick beds on steep slopes, — an assertion which has been abundantly disproved by observations in different parts of the world.

It is in this condition of dome-shaped elevation, caused by pressure from beneath, that Vesuvius is supposed to have been at the time Spartacus camped in its crater, just before the great eruption of 79. At the time the explosion took place, and the hidden forces obtained an outlet, one side of the crater of elevation was blown off, and an ordinary ash and cinder cone began to form in the cavity. The same mode of formation is claimed for Etna by Élie de Beaumont, one of the most zealous supporters of Buch's theory, who maintained that the lower portion of this great volcano was quite distinct in its formation from the upper; that the one was formed beneath the sea by the elevation of horizontally deposited

strata, while the other, or the cone proper,—which is eleven hundred feet high and has as steep an angle as thirty-two degrees,—was built up by subaerial accretions exclusively.

Buch applied his theory to the Peak of Teneriffe, of which he made a most detailed examination, and endeavored to explain by it the formation of the great semicircular wall which encloses the peak itself and the cone of Chahorra. This encircling precipice is, in places, full two thousand feet high and no less than eight miles in its longest diameter. Buch also visited and described with minuteness the beautiful island of Palma, a little west of Teneriffe, which is another of these great truncated cones, with a huge and deep cavity in the centre, called by the natives a *caldera* (kettle), from three to four miles in diameter, and walled in by a precipice varying from fifteen hundred to twenty-five hundred feet in vertical height. This boundary wall is so steep and unbroken that there is only one place where a descent is possible even on foot.

This kind of structure—namely, an encircling ring, of enormous dimensions compared with those of ordinary craters, with a cone in the centre—is quite common, and is especially well seen on some volcanic islands, where the internal structure is revealed by breaches made by the sea in the exterior wall. The interesting island of Santorin, in the Grecian Archipelago, is a good instance of this kind of arrangement, the volcanic fires here having been active of late, and the region one which has furnished material for a considerable number of volumes, as already mentioned. The island of Nisyros has a similar structure, the nearly circular crater being three miles in diameter and surrounded by a rim which rises from two thousand to twenty-three hundred feet above the sea. The island of St. Helena is described by Mr. Darwin as a trachytic volcano, encircled by a broken ring of basalt, measuring eight miles in diameter one way and four the other; the internal cliff faces are nearly perpendicular, except that they have in some places flat projecting shelves or ledges cut around them in parallel curves. Barren Island, in the Bay of Bengal, and the Mauritius, are other excellent examples of the same interesting type of structure. The encircling crater ring of the last-named island measures no less than thirteen miles in diameter.

Lyell, in the tenth edition of his "Principles of Geology," published two years since, has gone pretty thoroughly into the question of the applicability of Buch's theory to both Vesuvius and Etna, giving the results of his own repeated and recent examinations of these classic volcanoes, and pointing out that many important facts had been misapprehended by those geologists who had endeavored to show that the crater-of-elevation theory was the only one applicable to explain their form and structure. Hoffmann, many years ago, after a careful study of Vesuvius, abandoned the theory of Buch, which he had previously maintained. Of eminent French geologists, Cordier and Constant Prévost were also opposed to the idea of the building up of volcanoes in any other way than by the piling of one layer of ejected materials upon another.

The principal difficulty which those who do not support the crater-of-elevation theory have to meet is the enormous size of some of these great encircling rings, which would seem at first too large to be the result of explosive forces, implying as they do an astonishingly violent action and areas of vast dimensions over which the volumes of vapor must have been driven upwards.

There are craters of gigantic size, however, in regard to which it seems clearly demonstrated that they were formed in the ordinary way, that is, by the aggregation of materials erupted from a central orifice. Thus Kilauea does not bear any marks of being a crater of elevation; neither does the grand Haleakala, on the island of Manui, which is estimated to be some thirty miles in circumference. Junghuhn, who has made such a careful examination of the volcanoes of Java, gives it as the result of his observations that the great cones of that island have all been formed by eruption, and not by elevation; and he gives most excellent reasons for drawing this inference,— such reasons, indeed, as could only be successfully opposed by proving him to have misstated the facts. Similar conclusions have been arrived at by the writer of this article, after examining several of the great cones on the Pacific coast of North America.

If we consider what prodigious masses of material are thrown out, as already mentioned, in such eruptions as that of Tem-

boro or Coseguina, it will not be difficult to understand that a cavity of corresponding size must be left behind; and, as a means of enlarging such a cavity to an almost indefinite extent, we may call in both subaerial and submarine erosion, although the former has probably been usually by far the most effective agent in this respect. That any such great blister-like uplift of the superficial crust as was imagined by Humboldt to account for the dome-shaped base of Jorullo ever occurred seems, on the whole, highly improbable. His idea of a hollow crust or roof blown up over a vast empty space beneath will hardly be adopted by any geologist at present. Everything indicates, on the contrary, that, instead of there being a vacuum or a space filled only with gaseous substances under or over the centre of the volcanic action, there is much more likely to be a crowding together in that region of fluid material, seeking to find a vent. That great areas of stratified deposits might, under such conditions, be elevated into dome-shaped masses, is certainly not impossible; and yet it is questionable whether the fact of any such occurrence has ever been demonstrated.

It is indeed curious that the great name of Buch — a man once the very leader of geological science, and to whom Humboldt dedicated his *Kleinere Schriften* in these words: "Dem geistreichen Forscher der Natur, dem grössten Geognosten unseres Zeitalters, Leopold von Buch" — should for many years back have been most frequently quoted in order to bring forward fresh evidence against some one of his favorite theories, or to show how thoroughly he misapprehended some great geological phenomenon, like that of the distribution of the glacial boulders in Switzerland. Still the fact, however discouraging it may seem to those looking simply to permanence of personal reputation, is, in reality, an indication of progress in the science. Had Buch made a thorough examination of the geologically classic region of Southern Tyrol, he never would have given to the world a theory so entirely unsupported by facts as that by which he sought to explain the formation of the wonderfully picturesque cliffs of dolomite which have made that country so celebrated, and the origin of the rock of which they are composed. The day of generalizations of a magnitude

entirely disproportionate to the slender base of facts on which they rest has passed away; or, at least, the practice of bringing such theories forward with the positiveness, and upholding them with the obstinacy, of a Buch is one which is no longer in vogue.

There are, indeed, many geological phenomena the theory of which is obscure and difficult, and for whose final elucidation the stock of accumulated observation is still insufficient. If, with the view of directing attention to deficiencies in this stock, rather than of parading his actual knowledge, the geologist groups these facts together, and endeavors to show in what direction they seem to point or what the ultimate solution of the problem will probably be, he will, if his work be done in the right spirit, not incur the charge of rashly generalizing or of endeavoring to force his opinions on others. Among the obscurest and yet most attractive topics of geological investigation it would be safe to include the theory of volcanoes and earthquakes, and especially the connection of their phenomena with those movements of the earth's crust, which have resulted in the formation of continents and mountain-chains, and which, by altering the relative level of land and sea, have played the principal part in the long series of events that have been going on since our planet became the theatre of geological changes. This article, and one in the preceding number, may be considered as leading the reader to a point from which he will be able, with profit, and, it is to be hoped, not without pleasure, to survey the indicated field, and we shall endeavor at a future time to act as his guide in such a survey. Before closing, we must add a few pages to what has been said in a previous article, in regard to the geographical distribution of volcanoes, or their arrangement upon the earth's surface.

By far the most interesting fact in this connection is the proximity to the ocean of almost all active volcanic vents. Probably nine tenths of them are distributed around the Pacific, forming what has been aptly called a "circle of fire" full twenty thousand miles in length. The islands on the west side of that ocean form almost a continuous chain, beginning with the Aleutians on the north, and extending to New Zealand on the extreme south. This is pre-emi-

nently a region of active volcanism, for hardly a single one of the numerous islands in the various groups of which this belt is made up is entirely destitute of active vents, while on some of them they are crowded together by the hundred. In the groups of the Formosa, Philippine, Molucca, and Sunda Islands, there is perhaps the greatest concentration of volcanic energy which our planet exhibits. Nor is the east side of the Pacific less bountifully supplied with indications of igneous activity. Along the whole coast, from Patagonia to Alaska, the eruptive formations are displayed on the grandest possible scale, although the regions of present activity are sometimes widely separated from each other, and the volcanic belt, taken as a whole, presents evidences of a very considerable slackening of its energy since the close of the Tertiary period.

In the South American Andes the active volcanoes are chiefly limited to three great systems,—those of Chili, Bolivia, and Quito. Each of these has its grand cones, among which are the highest points in the world, with the exception of a few in the Himalaya. Aconcagua, the monarch of the Chilian group, lacking not much of twenty-three thousand feet in height, has been generally supposed to be a volcano, and was even reported by Darwin as having been in eruption in 1835. Some doubts have been thrown on this statement, however, by M. Pissis, a topographical engineer, who has been employed for years by the government of Chili in making a map of that country, and who maintains that Aconcagua consists of rocks of the Cretaceous series. It is curiously indicative of the feebleness of the spark of scientific inquiry which is kept alive even in the most enlightened of all the South American states, that so interesting a question should not have been definitely settled a long time ago. Still higher than Aconcagua is Sahama, chief of the Bolivian group, and only surpassed in elevation, on the American continent, by Illimani and Illampu. It is twenty-four thousand feet high, or one thousand feet higher than Chimborazo, which was long supposed to be the most elevated mountain mass of the New World, but which, although the loftiest of the magnificent group which surrounds the plain of Quito, is only 21,420 feet in height. Off the coast of Central and South America, at a consid-

erable distance, however, are groups of volcanic islands, with long intervals between them, which may be compared with the similar, but far more closely crowded ones on the opposite side of the Pacific. Along the line of these groups, within the intervals between them, frequent volcanic submarine eruptions have been observed, which have given rise to islands; these, however, have since been mostly washed away. If we may judge of the future by what has occurred in the past, it would be safe to predict that, as volcanic action dies out on the present coast line, a new belt will be gradually added to the continent on the west side. We might, without being considered as indulging in a fanciful speculation, say that the process of adding such a belt on the Asiatic side was already far advanced, while on the American it is just beginning. The most remarkable instance of insular volcanism on the east side of the Pacific is the group of the Galapagos, five hundred miles off shore, in the latitude of Quito. This group consists of five principal islands and several smaller ones, all volcanic. Craters have been seen in eruption on two of these, and on several of the others the streams of lava have quite a fresh appearance. The number of craters on the group is very great, having been estimated by Darwin at as high a number as two thousand.

The volcanic phenomena of the west coast of North America are on a still grander scale than those of the southern half of the continent, as far as the extent of the area covered by igneous products is concerned. There are not, however, as many very lofty cones, and not, in general, as much present activity. The highest development of volcanism on that coast seems to have occurred just at the close of the Tertiary epoch, and at that time the activity of the internal forces must have been prodigious. In spite of the immense erosion which has taken place since that time, the proofs of this activity are everywhere visible along the whole line of the coast from Central America to Alaska. The regions of active volcanic excitement on the Pacific coast of our continent are at present but two in number, and these are placed at the two extremities of the line, one in Central America and Southern Mexico, the other in Alaska and the Aleutian Islands. The southern region is

divided into two groups, the Central American and the Mexican; the former begins with the volcano of Chiriqui and extends to that of Soconusco, on the Isthmus of Tehuantepec, — a distance of full eleven hundred miles. This group is remarkable, not only on account of its parallelism with and close proximity to the coast, but for the number and size of the cones of which it is made up; of these there are more than fifty, almost all on the summit or else on the western flank of the Cordilleras. Perhaps, with the exception of Java, there is no region in the world where the volcanic vents are so crowded together. Of all the eruptions which have taken place here during the historical period, that of Coseguina, in 1835, already mentioned, was the most astonishing. The ashes thrown out at that time produced darkness for two days over a great extent of country, and covered an area as large as that of New England to the depth of several feet, the noise being heard in Jamaica and at Bogota.

Four hundred miles north of Soconusco, and exactly in a line with the prolonged axis of the Central American volcanic belt, rises the cone of Popocatapetl, generally considered the loftiest point of North America, and certainly the highest which has been accurately measured. Its only possible rival is its near neighbor, Orizaba, which has been made by some late, but not very trustworthy, measurements a little the higher of the two. Popocatapetl has been repeatedly measured with closely coincident results, so that we probably know its height within twenty-five feet; it is about 17,750 feet. Both these great cones belong to the chain of lofty volcanic vents which traverses the continent, in the direction of east and west, nearly in the latitude of the city of Mexico. Beyond this belt to the north, within the limits of Mexico, there are no active volcanoes; nor are there any on the peninsula of Lower California, as is uniformly reported in all the books; there are but few volcanic cones even, although rocks of this character in the form of dikes and sheets of lava are abundant in some parts of the peninsula. The volcanic formations on the mainland opposite are extensive and wonderfully varied in character; but they all belong to a past epoch of activity.

Crossing the Mexican boundary, and entering our own

territory, we find eruptive rocks abundant; and, on reaching the parallel of 35°, a little to the north of the centre of Arizona, another great volcanic belt may be traced across the Cordilleras, in a line transverse to their general trend. The most prominent cones of this belt are Mount Taylor, San Francisco Mountain, and Bill Williams's Peak, all magnificent mountains, probably between twelve and fourteen thousand feet high, but none of them has been ascended or accurately measured. They rise grandly from the plateau of horizontally stratified rocks, and are surrounded by vast lava fields bearing all the marks of having been erupted at no very remote period, although there are no indications of present activity.

Passing up through California and Nevada, we find all along both slopes of the Sierra Nevada, and on the parallel ranges east, entirely through to Salt Lake, abundant evidences of former volcanic action, on the grandest possible scale. On the east side of the mountains, this condition of activity seems to have ceased at the commencement of the present geological epoch, or at least to have diminished greatly in violence. The only indications of present volcanic activity along the Sierra Nevada, south of the north line of California, — aside from the numerous hot-springs, — are some comparatively faint remains of solfataric action on a few of the highest points. Thus Lassen's Peak, for instance, has several quite large areas where sulphurous gases escape from pools of hot water and boiling mud, while near the summit of Mount Shasta, amid the eternal snow, there is a hot-spring from which sulphurous vapors are constantly issuing. Between these two lofty volcanoes, one nearly 11,000 and the other 14,440 feet high, there are many others, some with wonderfully well-preserved craters, looking as if of very recent formation, yet entirely destitute of any traces of present activity. On the eastern slope of the Sierra, near Mono Lake, are a number of lofty and beautifully regular cones with well-defined terminal craters, yet apparently quite extinct. All through the State of Nevada, indeed, the mountain ranges are extensively flanked by vast accumulations of lava, and when we cross the Humboldt River, and traverse the region north of the parallel of 41°, we find a continuous covering

of volcanic materials extending over all the northern portion of Nevada and California, as well as Southern Idaho, Eastern Oregon, and Washington Territory. This region, which is covered almost exclusively with basaltic lava, is but little, if any, less than six hundred miles square, and occupies an area considerably larger than France and Great Britain combined. It is by erosion of rocks of this character that the many beautiful waterfalls of the Snake, Pelouse, and other rivers have been formed. Those of the Snake River are described by the few who have seen them as of surpassing grandeur. They must be among the very finest in the world, taking into account height, volume of water, and attractiveness of the surrounding scenery.

North of the California line the belt of nearly extinct volcanic activity is continued in the Cascade Range, — the prominent peaks and cones of that chain, which is in fact a continuation of the Sierra Nevada, being all of volcanic origin. The best known ones south of the Columbia River are — naming them from south to north — Mount Pitt, the Diamond Peaks, the Three Sisters, Mount Jefferson, and Mount Hood. The latter is a magnificent cone, very conspicuous over a great extent of country, and much looked up to and respected by the Oregonians, who were very wroth at having its boasted 17,000 or 18,000 feet cut down by the ruthless hand of science to 11,225. North of the Columbia are Mount Adams and Mount St. Helens, which are in nearly the same parallel; then, Mount Rainier, standing in solitary grandeur about seventy miles east-southeast of Olympia; and finally, Mount Baker, near the line of British Columbia. Of these great cones, Mount Rainier is the noblest: as seen from Puget's Sound, covered with snow nearly down to its base even late in the summer, it is truly a magnificent object. Its summit has never been reached, so far as we can ascertain, while all the other important cones of this region have been repeatedly ascended. That any of these volcanoes have emitted streams of lava since the country became known to the whites is not probable; but that ashes have been thrown out from two of them, Mount St. Helens and Mount Baker, seems to be well authenticated. The newspapers have frequent accounts of columns of vapor being seen to issue

from Mount Hood, and of other indications of activity being displayed by the great cones which are such conspicuous objects to those passing up and down the Columbia. These stories, when not intentional fabrications, may perhaps be attributed to the fact that sometimes on clear days the moisture in the air blowing from the ocean is condensed around the cool, snow-covered summits of the cones, so as to have somewhat the appearance to a not very critical eye of clouds of vapor issuing from them. We obtained pretty satisfactory testimony that Mount Hood at least had shown no signs of activity during the past eight or ten years.

There are also most conflicting statements with regard to the condition of the volcanoes through British Columbia and Alaska. Thus Scrope, a careful and trustworthy authority, says of Mount St. Elias, that it has certainly been seen in eruption, while Grewingk, a well-known geologist who explored that region and carefully examined all the published authorities on the subject, declares that none of these volcanoes — St. Elias, Edgecombe, Fairweather, etc. — have been active during the historical period, or, at least, that there is no evidence of any such activity.

J. D. Whitney.

Art. IX. — CRITICAL NOTICES.

1. — *The Pre-Columbian Discovery of America by the Northmen, illustrated by Translations from the Icelandic Sagas. Edited, with Notes and a General Introduction, by* B. F. De Costa. Albany: Joel Munsell. 1868.

More than thirty years ago the hope was expressed in this Review that the interesting documents relating to the discovery of America by the Northmen, which had just been published in the *Antiquitates Americanæ*, might be put into an English dress, and prepared for the perusal of the general reader. In the following year appeared the work of Mr. Joshua Toulmin Smith, "The Northmen in New England, or America in the Tenth Century." To heighten the interest of the subject, Mr. Smith threw his discussion into the form of dialogue; but